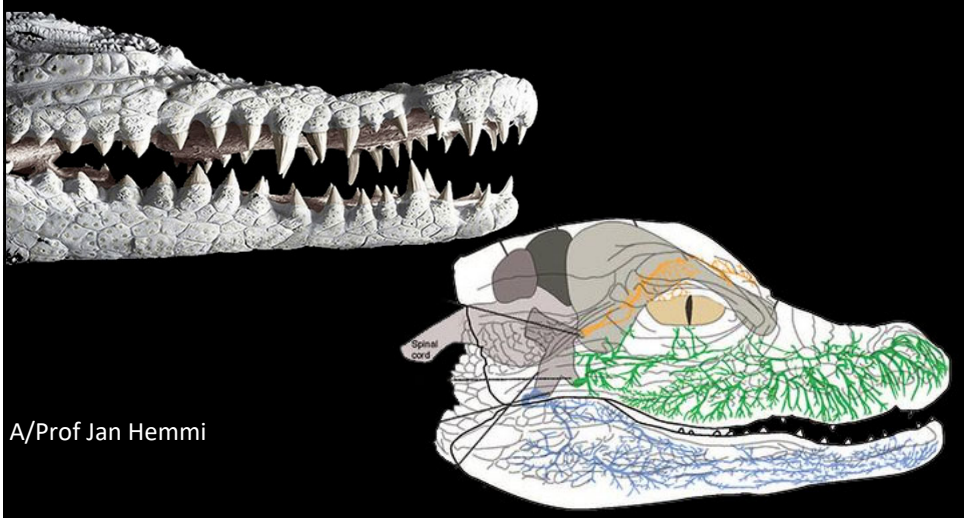
Mechanoreception: 2. Sense of Equilibrium



A/Prof Jan Hemmi

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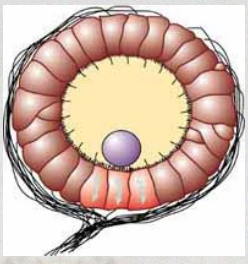
Sense of Equilibrium

- Answers 2 fundamental questions:
  - Which way is up?
  - Where am I going?
- Measures gravity and angular acceleration
- In most animals signals from mechanosensory balance organs are combined with visual signals to sense body orientation

2

Sense of Equilibrium Statocysts

- Simplest organ to detect position and acceleration with respect to gravity
- Faster than vision, used to stabilise angle of view
- Hollow fluid-filled cavity lined with mechanoreceptive cells that make contact with statolith
- Present in most animal groups (from the Cnidaria onwards!)



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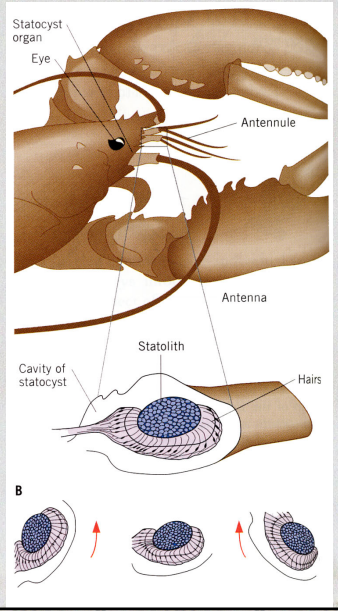
Sense of Equilibrium Example: the lobster



- Statocyst located at base of antennae
- Statolith are grains of sand, replaced after every molt
- Brain can calculate body angle depending on which population of hair cell is stimulated
- Experiment to test importance of statocysts: iron filings

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Sense of Equilibrium Statocysts

- Insects do not have statocysts, water-living insects often use air bubbles attached to mechanoreceptors to sense gravity
- Cephalopods
  - Highly developed
  - Used for eye movement response, control of posture and swimming and control of body shading

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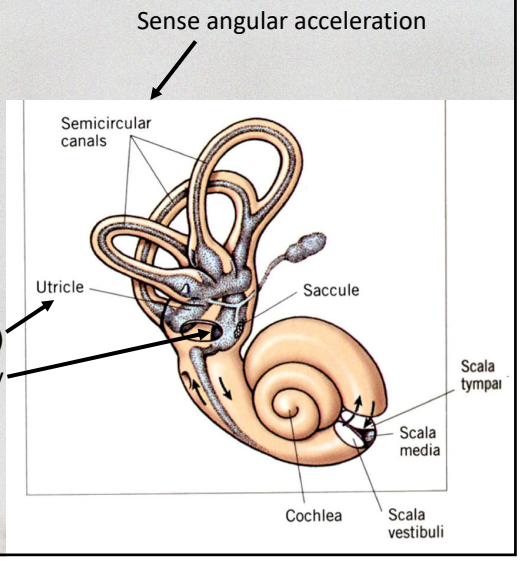
Sense of Equilibrium Vestibular system

- Vertebrate ears: hearing and sense of equilibrium (vestibular system)
- Both systems are based on hair cells as sensory cells and filled with endolymph
- vestibular system: 6 degrees of freedom

  Otolith organ (utricle and saccule) similar to statocyst, senses gravity



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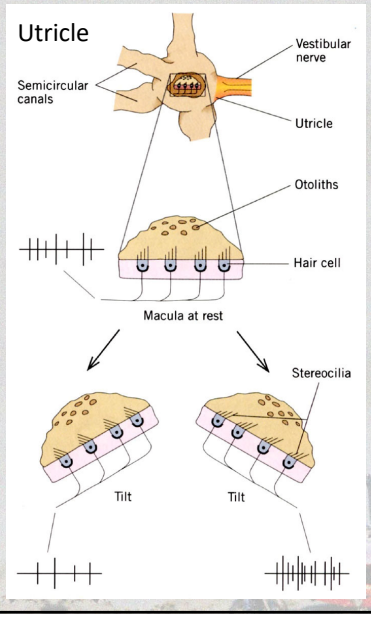
Sense of Equilibrium

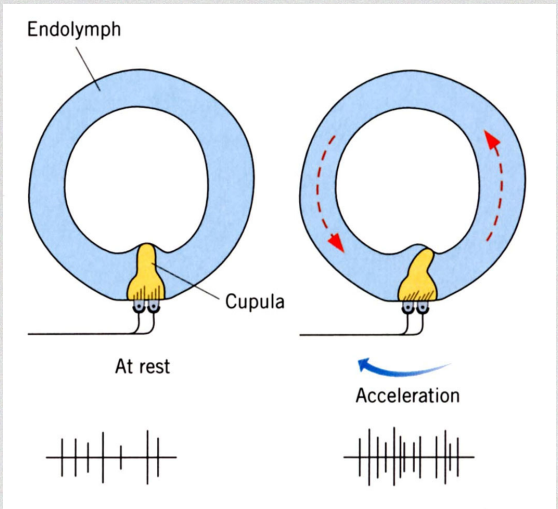
Otolith organs

- **Utricle**: head angle (shown on right)
- **Saccule**: linear acceleration (side-side, up-down)



Sense of Equilibrium

Semicircular Canals I

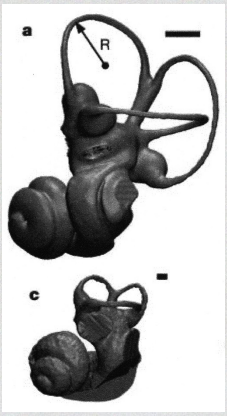


- Senses angular acceleration
- Relative motion of endolymph detected

Sense of Equilibrium

Semicircular Canals II

- Phasic response - detecting acceleration and deceleration
- Canals oriented in 3 dimensions - allows detection of head rotation in any plane



Cetaceans have very small semicircular canals

Spoor et al. (2002)

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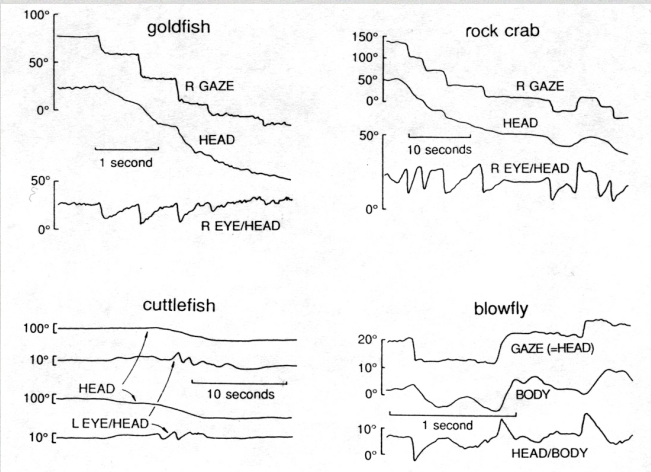
Sense of Equilibrium

Vestibulo-Ocular connection

Visual and mechanosensory feedback are combined for gaze stabilisation when the head moves

Vestibulo-ocular reflex (VOR)

Gaze stabilisation



Land (1995)

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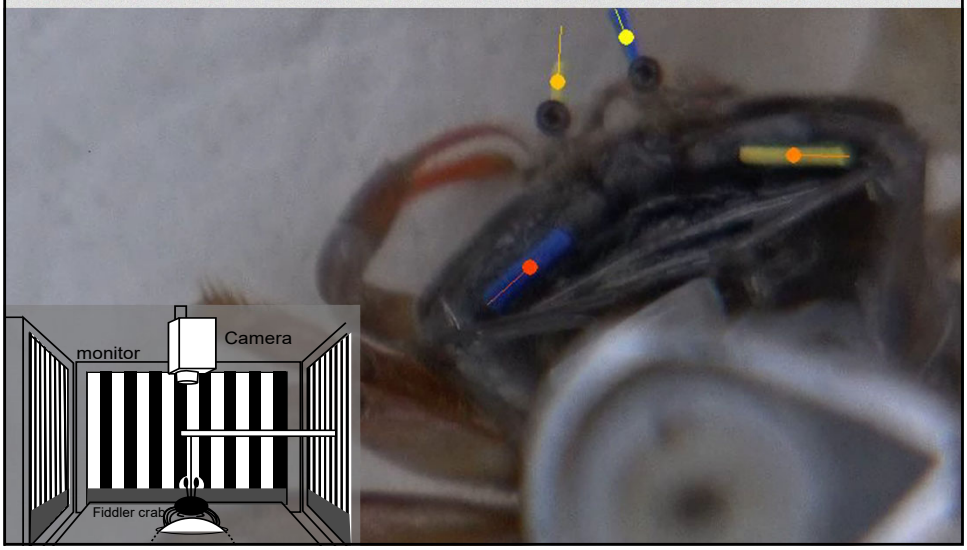
Eye movements in response to oscillating gratings

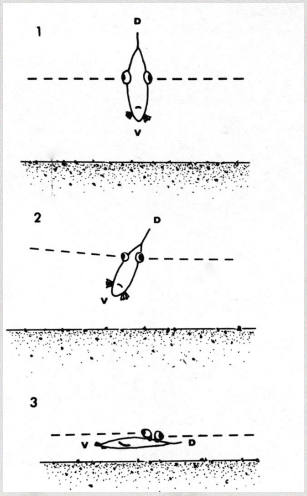


Dorsal Light Reflex

- Many animals integrate input from vestibular system and visual system for body orientation - normally gravity and highest light intensity indicate the vertical
- If artificially lit from the side animal will tilt towards the light to a position between vestibular and visual cues
- Useful for detecting sensitivity to a stimulus

Preuss & Budelmann (1995)

Problems of a flatfish I



- Undergo a 90˚ tilt during development
- Dorsal light reflex one important part of metamorphosis
- Metamorphosis is light dependent
- Adults don't show strong dorsal light reflex any more

Finger (1976) Graf and Baker (1990)

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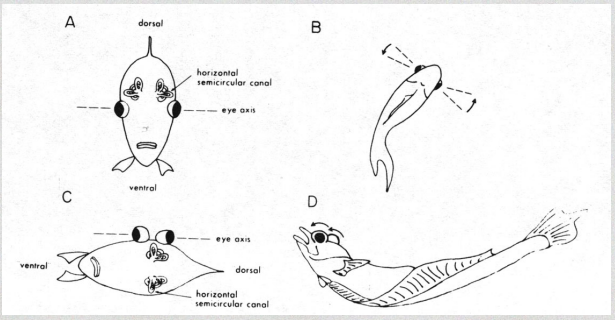
Problems of a flatfish II



- Horizontal canal is now vertical
- Vestibulo-ocular reflex still works perfectly due to adaptive plasticity
  - rewiring of connections that link horizontal canals to vertical eye muscles

Finger (1976) Graf and Baker (1990)

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Summary: Sense of Balance

- Found widely in the animal kingdom
- Measures gravity (statocyst, otolith) and angular acceleration (semicircular canals)
- Function: stabilizes gaze during head/body movements, provides feedback for body movements